Precision beta-spectroscopy in search for physics beyond the Standard Model

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Physics beyond the Standard Model

- High energy → LHC and other accelerators
- Low energy → precision measurements ↔ Standard Model predictions

Correlation measurements in nuclear beta decay

limits on possible S,T type currents in weak interaction

$$p \sim F(Z, E_e)\, p_e E_e (E_0 - E_e)^2 dE_e\, d\Omega_e\, d\Omega_\nu\, \xi \left\{ 1 + b\frac{m}{E} + a\frac{\vec{p}_e \vec{p}_\nu}{E_e E_\nu} + A\frac{\vec{J}}{J}\frac{\vec{p}_e}{E_e} + \ldots \right\}$$

Beta-neutrino correlation (a)

Beta asymmetry (A)

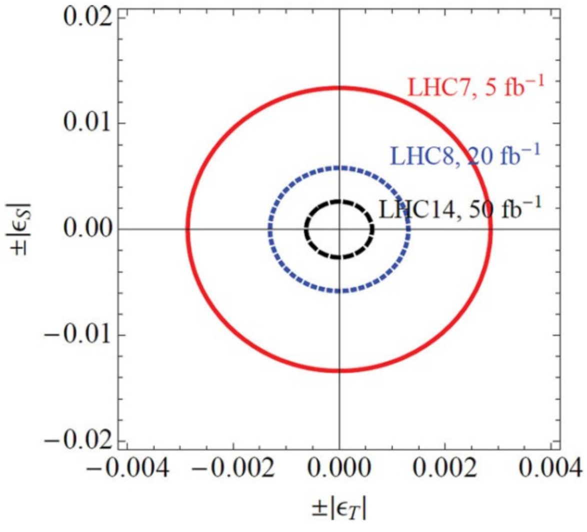
J.D. Jackson, Nucl. Phys. 4 (1957) 206
N. Severijns, Rev. Mod. Phys. 78 (2006) 991

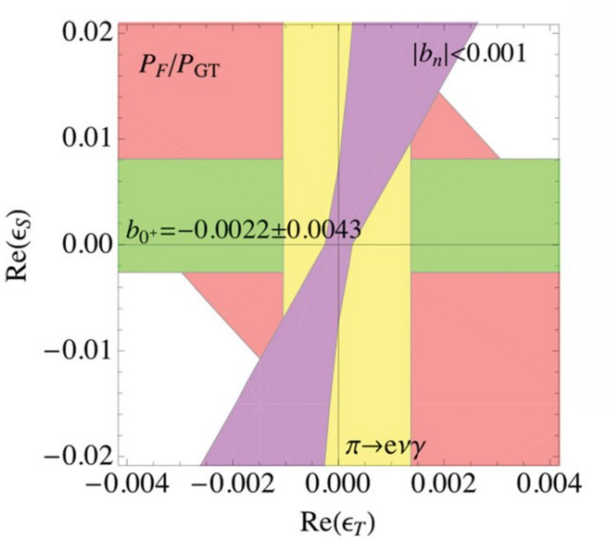
Physics beyond the Standard Model

Recent studies show that we should focus on the Fierz interference term

$$p \sim F(Z, E_e)\, p_e E_e (E_0 - E_e)^2 dE_e\, d\Omega_e\, d\Omega_\nu\, \xi \left\{ 1 + b\frac{m}{E} + a\frac{\vec{p}_e \vec{p}_\nu}{E_e E_\nu} + A\frac{\vec{J}}{J}\frac{\vec{p}_e}{E_e} + \ldots \right\}$$

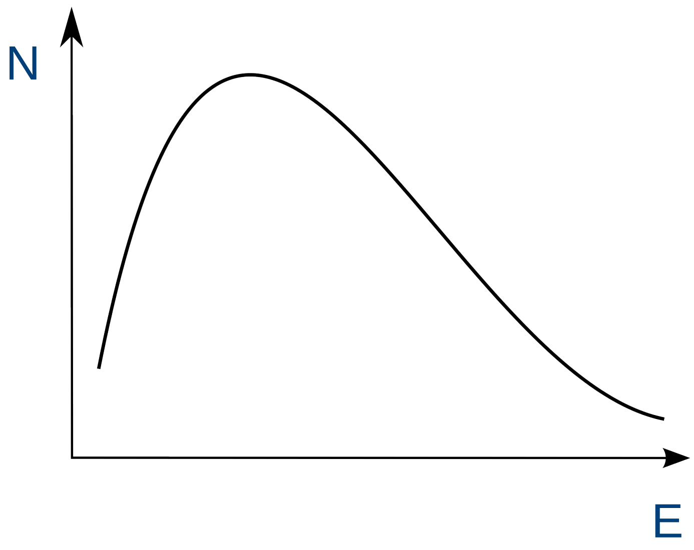
O. Naviliat-Cuncic, Ann. Phys. 525 (2013) 600





With sub-percent precision on the Fierz term beta-decay experiments remain competitive with LHC at the highest energies.

Shape of the beta spectrum



Standard Model spectrum shape

$$N_{SM}(E) = C\,F(Z, E_e)\,p_e E_e (E_0 - E_e)^2\, dE_e$$

Standard Model + New physics spectrum shape

$$N_{exp}(E) = C\,F(Z, E_e)\,p_e E_e (E_0 - E_e)^2 \left\{1 + b\frac{m}{E}\right\}$$

Ratio Experiment / Standard Model:

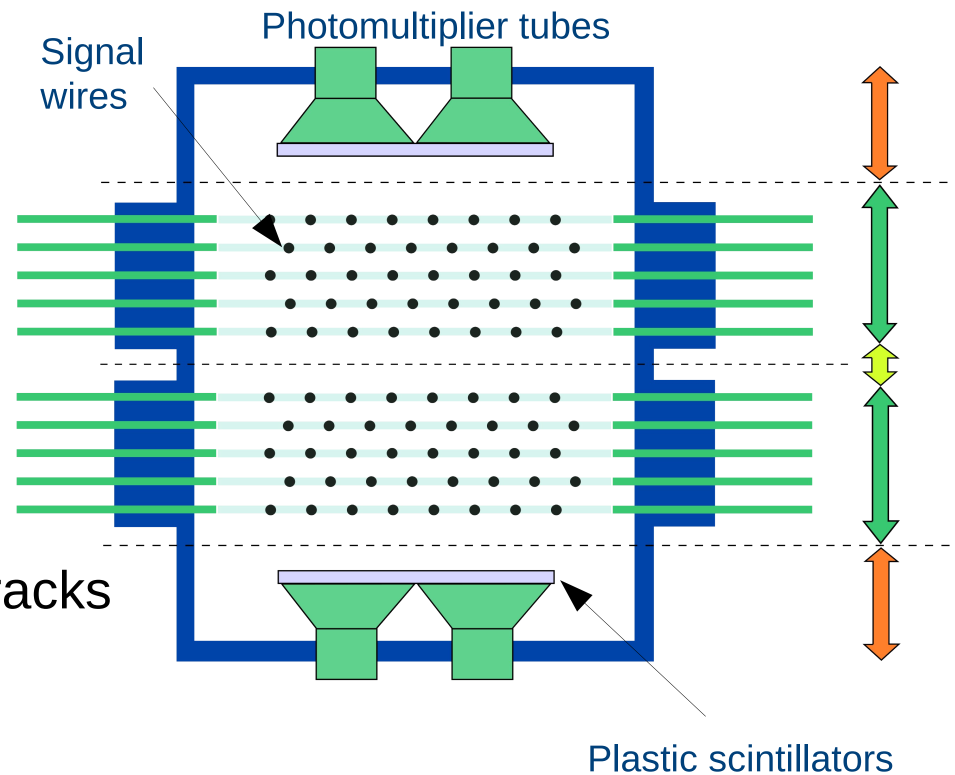
$$\frac{N_{exp}}{N_{SM}} = 1 + b\frac{m}{E}$$

Also sensitive to higher order corrections within the Standard Model

B. R. Holstein, Rev. Mod. Phys. 46 (1974) 789
V. de Leebeeck, to be published

The miniBETA spectrometer

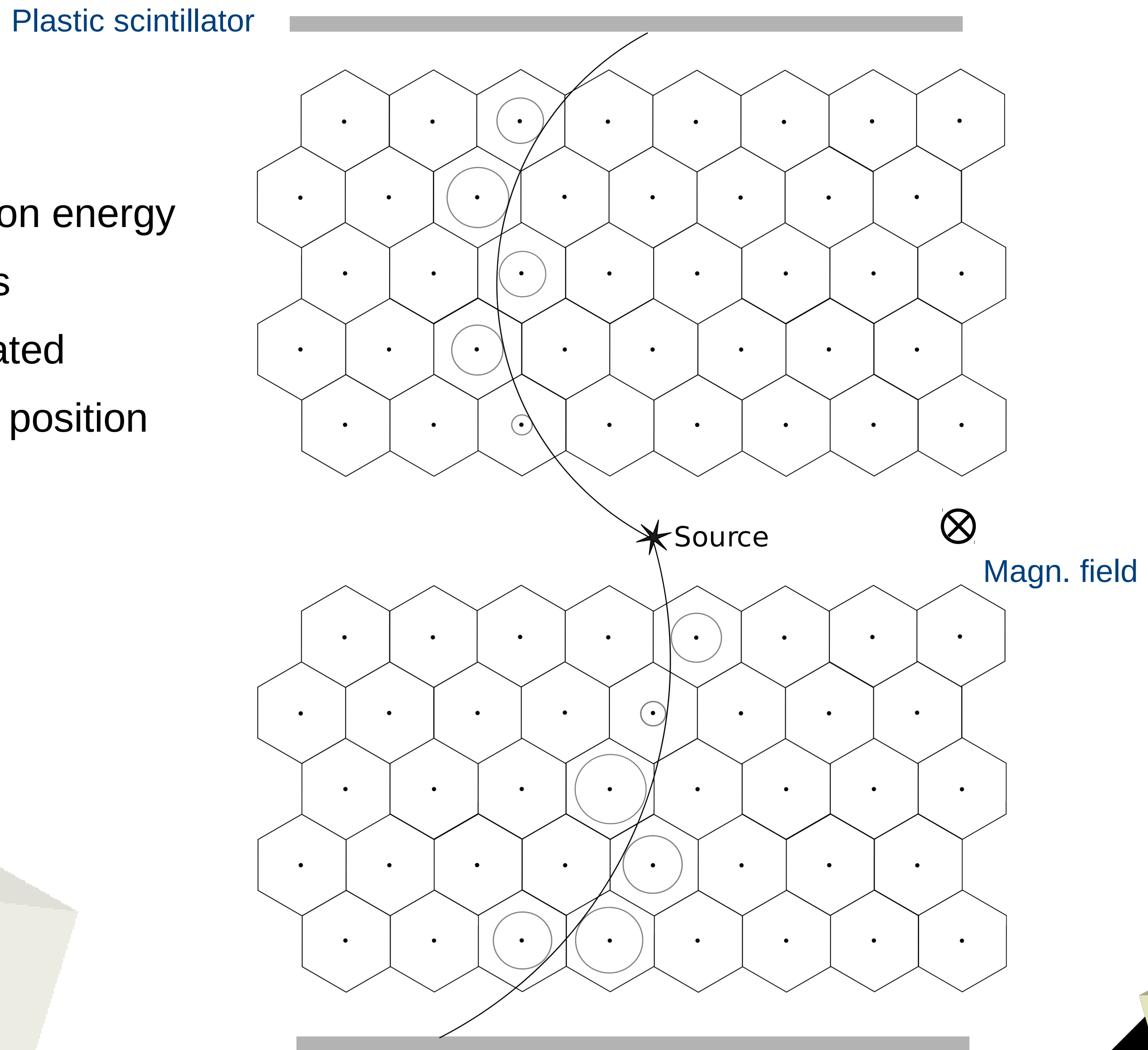
- Modular drift chamber
- High precision X-Y positioning
- Z position → charge division along resistive signal wire
- Hexagonal cell structure
- Plastic scintillators provide trigger
- Low pressure He gas
- Magnetic field → curved electron tracks



In collaboration with the Jagiellonian University, Cracow, Poland
K. Lojek, NIM A 611 (2009) 284

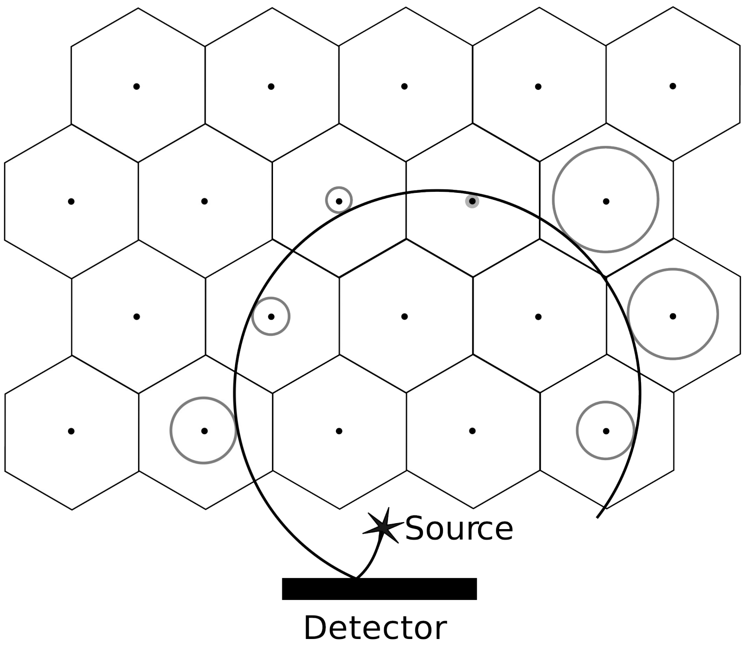
The miniBETA spectrometer

- Magnetic field
  - electron energy
- 80 signal wires
- 0.5 mm estimated uncertainty on position



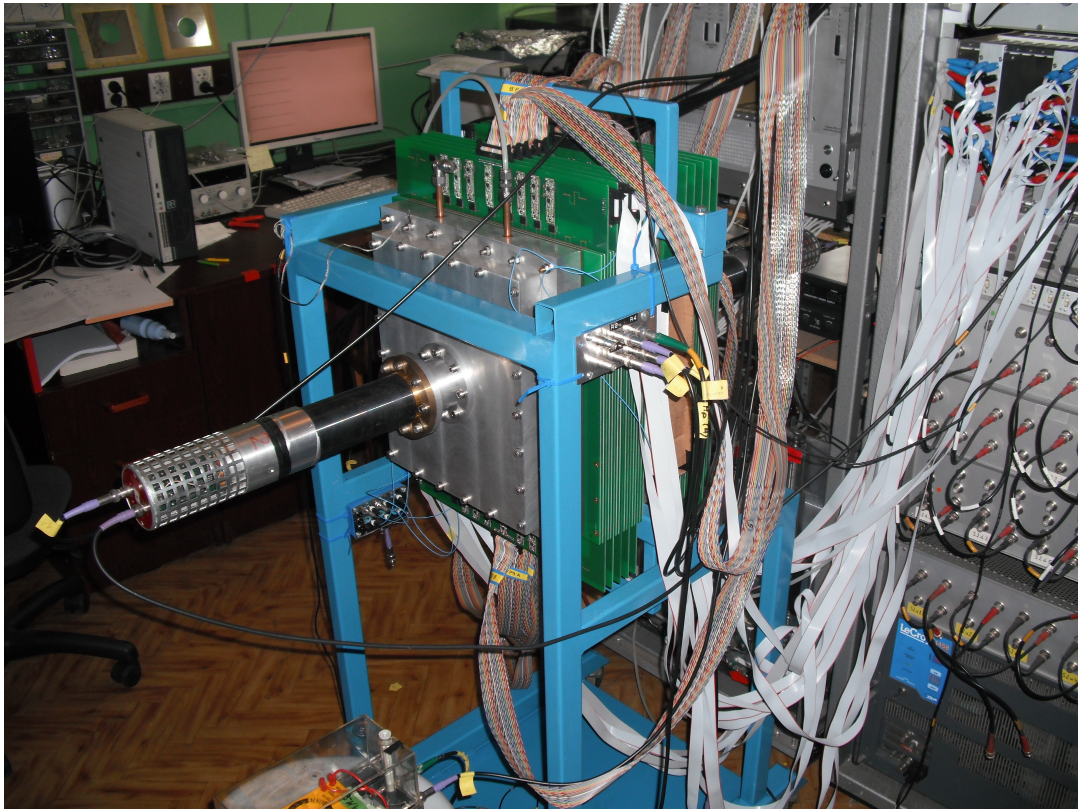
The miniBETA spectrometer

- Electron scattering studies
- Only one half of the setup
- Initial energy from
  track curvature + energy deposit
- Conversion electrons



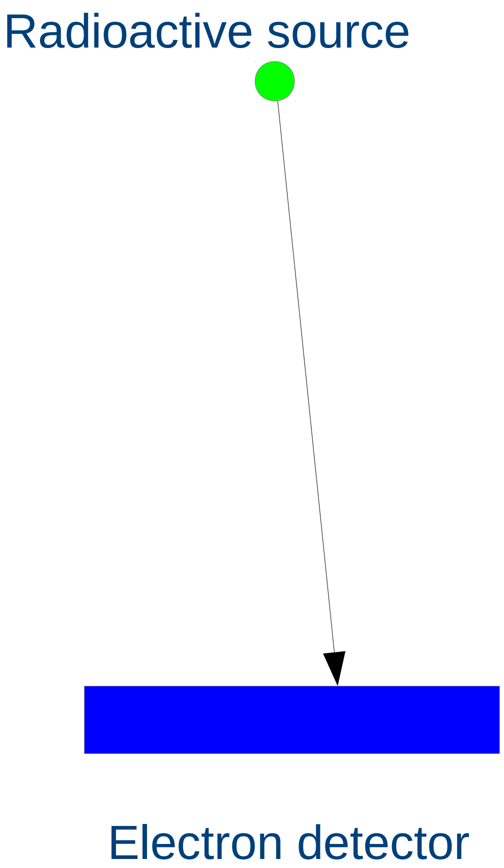
The miniBETA spectrometer

The next commissioning experiment is next week.

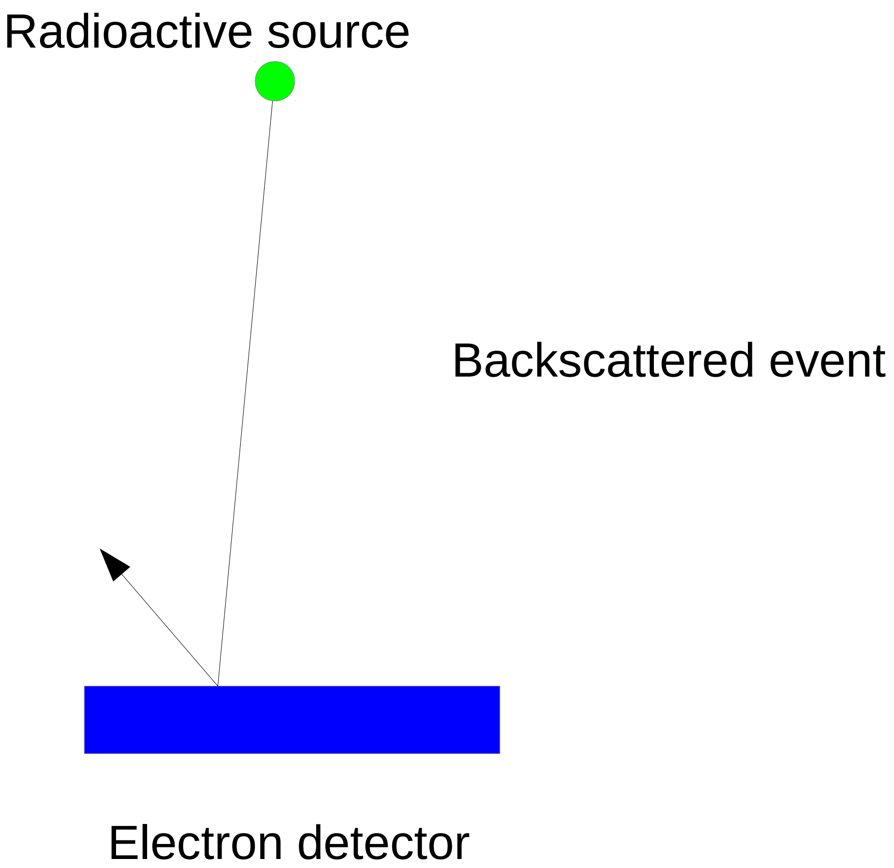


The setup is currently at the Institute of Physics, Jagiellonian University, Cracow, Poland

A simpler measurement

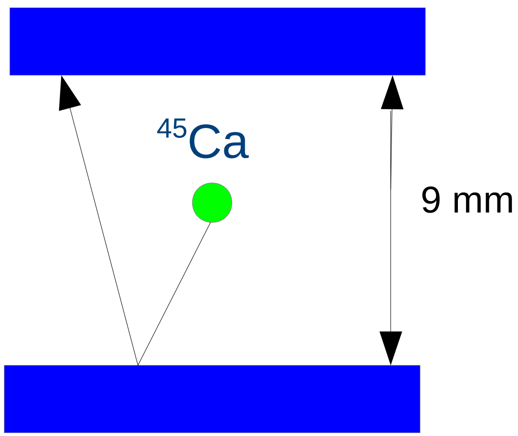


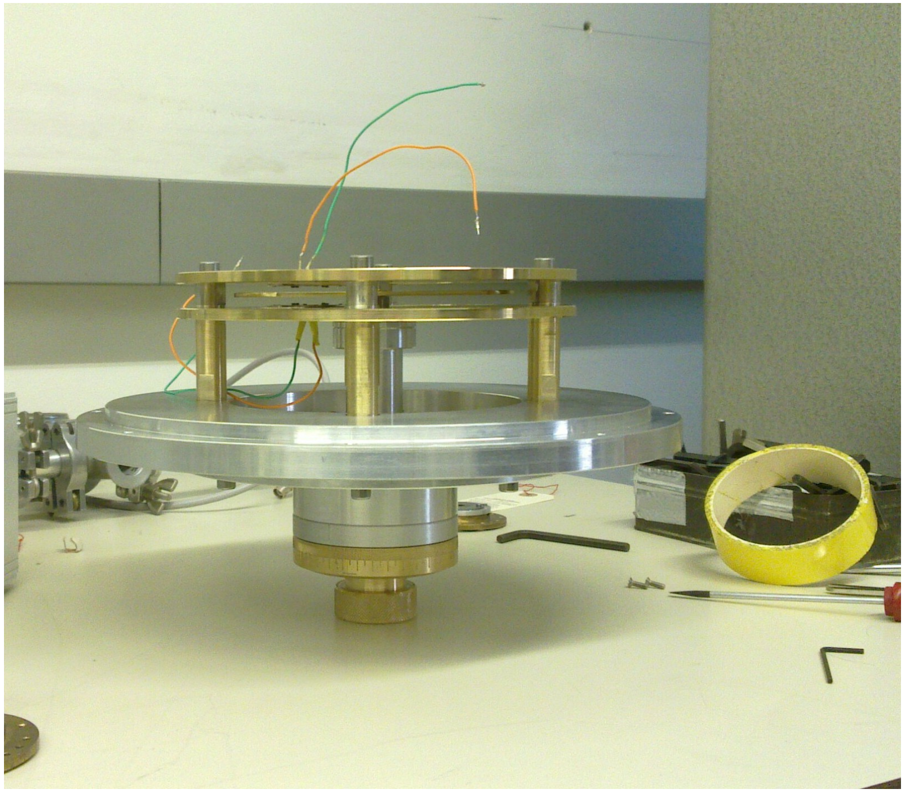
A simpler measurement



A simpler measurement

Use two detectors to “catch” a large amount of backscattered events.





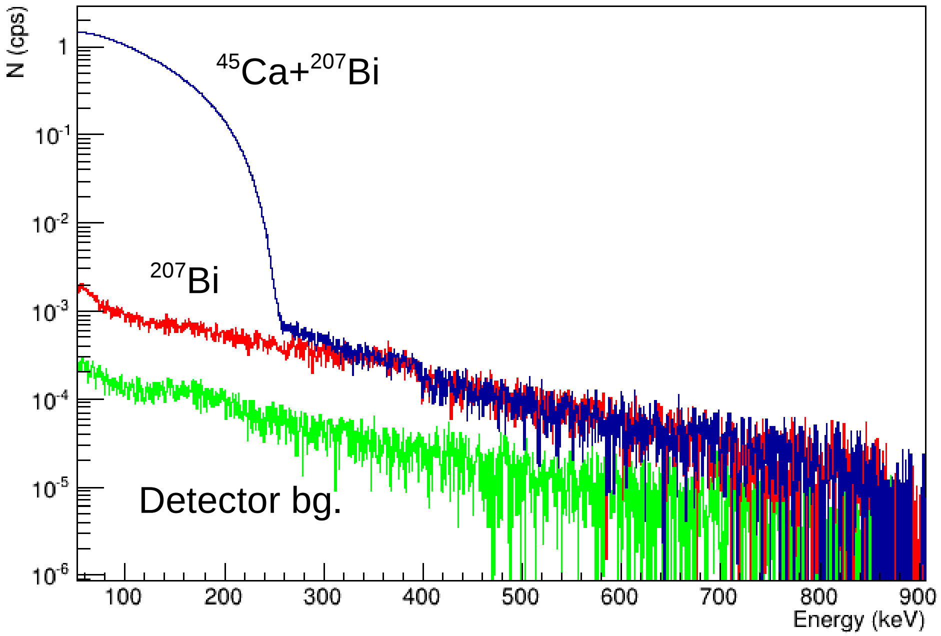
Use Geant4 simulations to estimate the effect of escaped backscattered events.

S. Agostinelli, NIM A 506 (2003) 250
G. Soti, NIM A 728 (2013) 11

Preliminary results

- Possible pile-up
  - new digital data acquisition system
  - reduce source strength
- Gain instabilities
  - temperature controlled electronics
  - Regular energy calibration

Beta spectrum of ^{45}Ca (E_0 =258 keV)



Conclusions

- Measurement of the spectrum shape is also sensitive to new physics
- miniBETA drift chamber
- Simple measurement with two detectors
- Accuracy on the 0.1% level or better is required